

### EAGLE = PICHER Electronics Division Joplin, MO

## SODIUM-SULFUR GROUP

# EPI SODIUM SULFUR PROGRAM

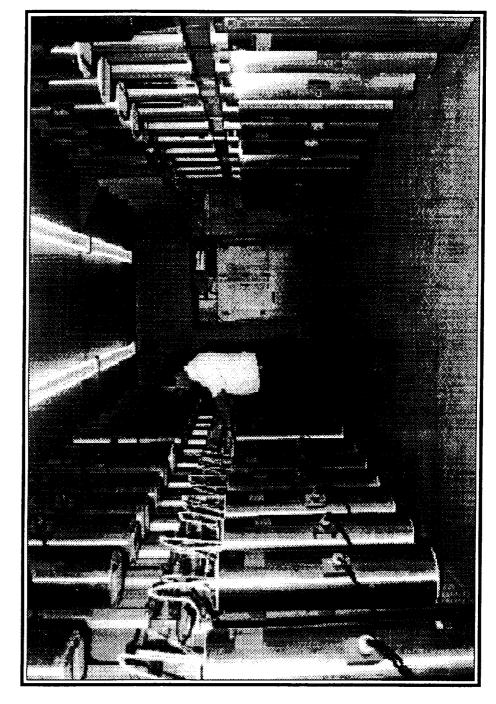
- NaS program initiated in 1986.
- EPI selected by USAF as sole developer for NaS LEO cells.
- Over 200 cells constructed for a variety of applications.
- Developed a eta" electrolyte production capability



Paulinna Pougity First

ADVANCED SYSTEMS OPERATION

## SODIUM-SULFUR GROUP



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## UR GROUP

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<u></u>	Electronics Division	Joplin, MO

**CELL SIZES MANUFACTURED** 

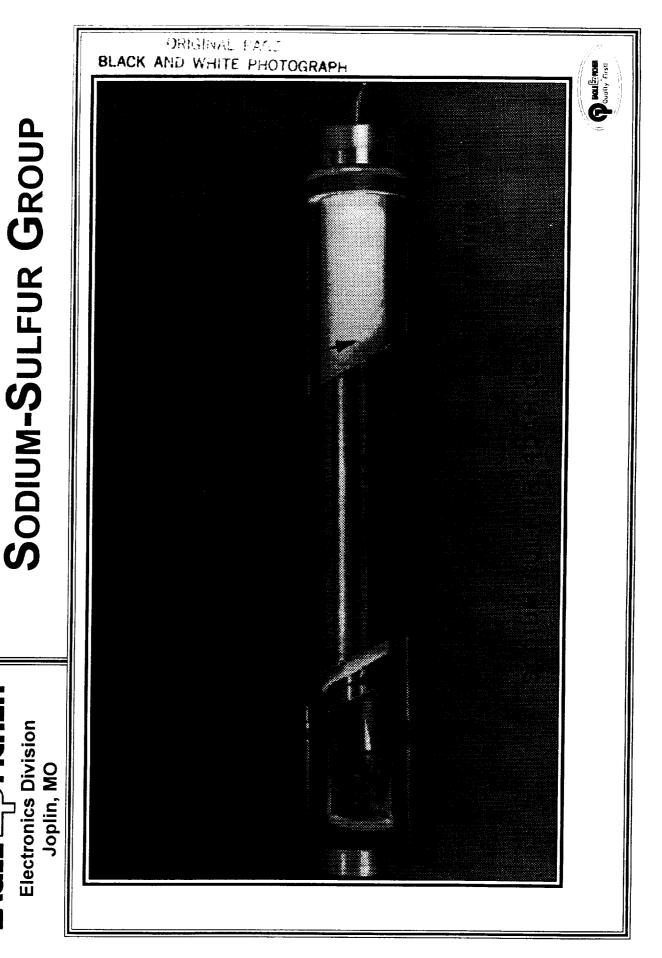
1.4" D X 12.3" L

**50 AH** 

600 gms (1.31 lbs)

1.4" D X 9.0" L

500 gms (1.10 lbs)



1992 NASA Aerospace Battery Workshop

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EAGLE F PICHER

-660-

Advanced Technologies Session

0-8



### SODIUM-SULFUR GROUP

AREAS OF IMPROVEMENT

- Resistance
- Cathode Performance
- **Parts Count**
- Weight
- Seals

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	Performa	rmance Improvement Demonstrated (16 Amp Discharge)	ement Dem Jischarge)	onstrated	
	Weight (grams)	Avg. Volts (Discharge)	Resistance (mOhms)	Spec. Energy (Whr/Kg)	Energy Dens. (Whr/L)
Baseline	509	1.64	17.6	119.1	266.9
Intermediate	909	1.74	10.6	127.3	283.6
Improved	500	1.89	6.7	139.8	307.8
 State-of-the-Art	455	1.95	5.8	158.5	334.0
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### "IMPROVED" DESIGN 50 AHR CELL

- 8,400 Cycles (>95% LEO, 60% DOD)
- On test 33 months
- Discharge resistance 8.3 milliohms (7.3 milliohms BOL)
- F1% 16.1 (14.0 BOL)
- Capacity 53.3 AHr (52.1 BOL)

D MARES MONTH AMPS DOD) 120 110 100 88 60 50 30 20 40 18 140150 6 7, F1(x) = 19.01CHARGE (45/30/25/22.5/20/17.5/15A) 130 (LEO 120 100 PERFORMANCE MINUTES OPEN CIRCUIT 50 CELL 40 Ê DISCHARGE (54 CYCLE 8148 IMPROVED 20 VOLTS 10 က 2.8 2.6 2.2 1.6 1.4 9 VOLTS

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### **AMPS** DOD) 60 20 Ø 420450 \ Ŋ 390 ற 360 Ê (CAP CONSTANT CURRENT CHARGE (15 A/5 300 PERFORMANCE 270 MINUTES 240 210 **=** 16.12 CIRCUI OPEN F1(%) 150 F1(%) æ CELL 120 CYCLE 8338 CYCLE 1119 A/2 A/25 DISCHARGE (25 IMPROVED 60 VOLTS 30 0 ٦. 2.8 2.6 2.2 2.4 4. 1.2 SITON

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D MAKEBINGER SODIUM-SULFUR GROUP 8104 6694 7243 8799 9809 ADVANCED SYSTEMS OPERATION Resistance - 50AHr "Improved" Cell 1719 **L**797 <u>6</u> € 4095 3200 3082 **8997** EAGLE F PICHER
Electronics Division 2002 1439 Joplin, MO 887  $\infty$ smdOm

\$018 SODIUM-SULFUR GROUP 6694 7243 8799 9809 ADVANCED SYSTEMS OPERATION Capacity - 50AHr "Improved" Cell 1719 1797 260≯ √C 3200 3082 8997 2002 EAGLE FOPICHER 1436 Electronics Division Joplin, MO 887 **2.00H-qmA** 50.00 80 80 80 80 42.00 40.00 56.00 52.00 46.00 44.00 58.00 54.00 60.00



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### SODIUM-SULFUR GROUP

SINGLE CELL TEST MILESTONES

- Over 11,000 cycles to date
- 43 month calendar life
- 3,130 AHr/cm<sup>2</sup> in cell testing
- 5,900 AHr/cm<sup>2</sup> in sodium-sodium testing
- Discharge resistance < 5 milliohms
- F1 of less than 5 (low rate charge)



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# ENVIRONMENTAL TESTING ACCOMPLISHED

- 30g's, 11ms Shock .....
- .. 15g's, 5 min. Acceleration .....
- ... 0.25g<sup>2</sup>/Hz, 300-1200Hz Random Vibration..

(0A=19.5g RMS)

- 7.5g peak, 5-2000Hz Sine Vibration....
- .. MIL-STD-810B, Method 507 Humidity .....
- 20 Cycles Freeze/Thaw ...

**AMPS** 60 50 **4** 98 20 0 420450 0 0 7, F1(%) = 11.62 390 360 CAP Ê CONSTANT CURRENT CHARGE (10 A/4 930 STATE-OF-THE-ART 300 PERFORMANCE 278 MINUTES 240 210 180 OPEN DISCHARGE (20 A) 96 TYPICAL VOLTS 90 Ø 2.6 ري در 1.2 ω. ..6 SIJON

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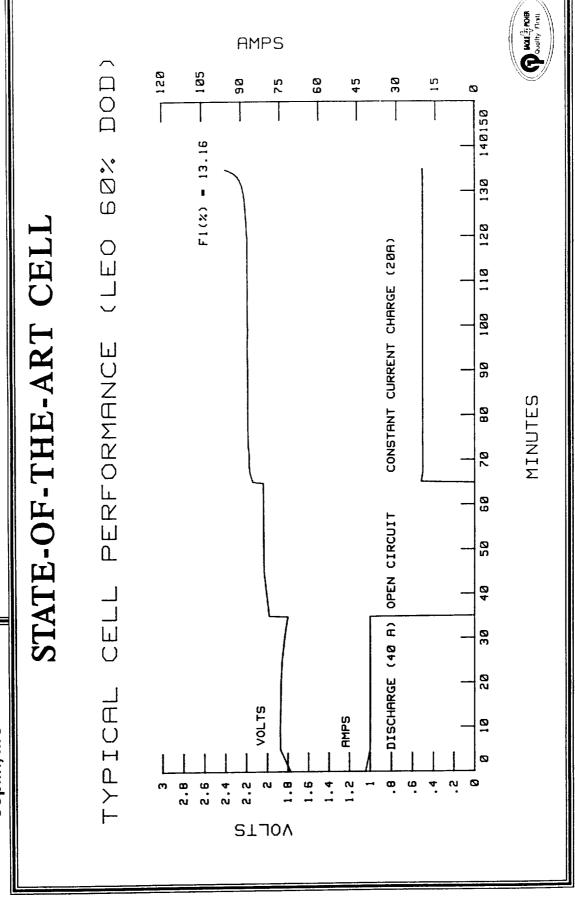
ADVANCED SYSTEMS OPERATION

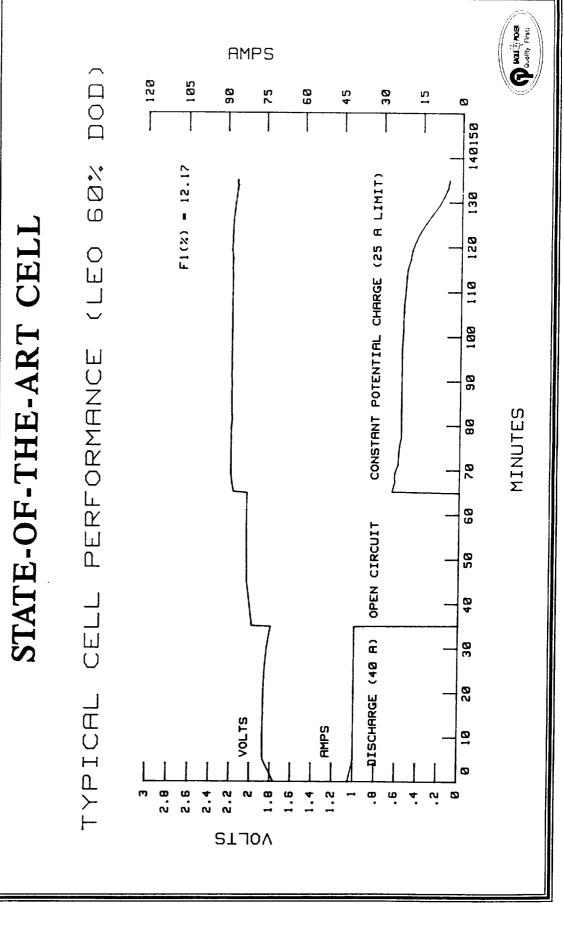
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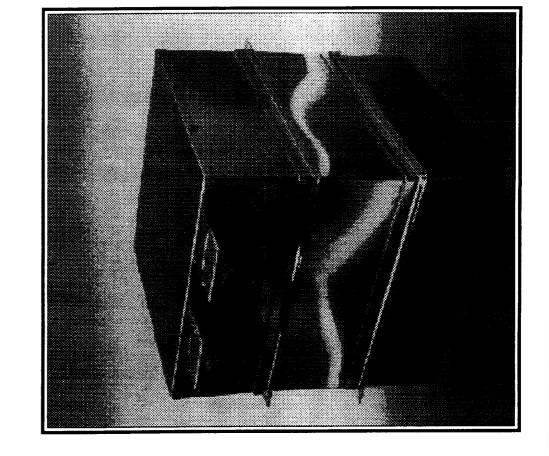
# SODIUM-SULFUR GROUP

### ENTRY LEVEL BATTERY

- Effort funded internally 1990-1991
- Three cell module
- Constant current charge/discharge Nominal 60% DOD (=30AHr) 1,000 cycles achieved
- 30 Whr/Kg
- Calendar life: 6 months



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## SODIUM-SULFUR GROUP

### Next Generation Battery Performance Projections

35 Amp-Hour cells

20 cell series string

Battery OCV: 42 Volts

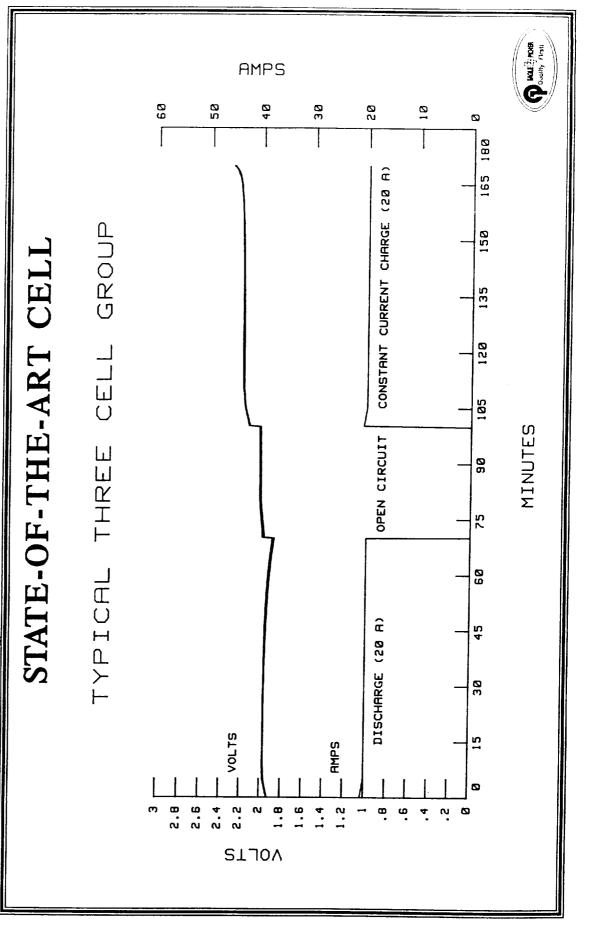
Battery working volts: 38 Volts

Weight: 13.5 Kg

Volume: 30 L

Energy Density: 100 Whr/Kg, 45 Whr/L





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AMPS 20 <u>.</u> 60 **4** 30 180 CONSTANT CURRENT CHARGE (20 A) 165 150 CELL GROUP STATE-OF-THE-ART CELI 135 120 105 MINUTES OPEN CIRCUIT TYPICAL THREE 60 DISCHARGE (20 A) 45 30 VOLTS AMPS .. 1.6 2. S VOLTS

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### SODIUM-SULFUR GROUP

### SUMMARY

Sodium Sulfur cell and battery designs continue to evolve with significant improvement demonstrated

- Resistance
- Rechargeability
- Cycle Life
- **Energy Density**
- Electrolyte Characterization